

IX. Oligopoly in Local Markets¹⁰⁵

Even in those cases where the consumer has a competitive alternative, in the form of cable, for example, the underlying competition is not likely to be robust. That is, the carriers are likely to have significant market power. The inadequacy of a facilities duopoly for ensuring consumer choice can be demonstrated in several ways. As a theoretical matter, duopoly is much more likely to lead to monopoly behavior. Game theory models show that when markets are occupied by a relatively small number of competitors, performance can suffer. In many models a competitive result requires several carriers to be in the market. The price-cost margin in the standard Cournot model of oligopoly interaction is inversely related to the number of competitors.¹⁰⁶ In other words, a duopoly in the broadband service market is not likely to perform competitively.

Game theory models typically assume that the competitors recognize their interdependence, but do not explicitly coordinate their behavior. This means that the resulting prices, while higher than the competitive level, may fall short of the monopoly profit maximizing level. By learning how to coordinate their actions, oligopoly firms may be able to raise prices above the Cournot level.

A number of factors facilitate the necessary coordination. The basic requirement, of course, is small numbers. In addition, if prices are visible to all the competitors, then cheating on any tacit agreement will be detected and therefore less likely to occur. Similarly, if the firms compete with one another in

¹⁰⁵ See Kelley Broadband Declaration.

¹⁰⁶ See, e.g., W. Kip Viscusi, John M. Vernon and Joseph E. Harrington, Jr., *Economics of Regulation and Antitrust*, Third ed., MIT Press, Cambridge, MA 2000, p. 108.

multiple markets, then they will be less likely to compete aggressively in any one of them due to the risk of retaliation.¹⁰⁷ Each of these facilitating factors is present in the local exchange business. Prices are well known to all competitors. Even without tariffs, the mass-market nature of the services generally requires standardized offerings. ILECs, cable companies and wireless providers are interconnected through multiple market contacts.

Among the harshest critics of oligopoly performance are the ILECs. They have been complaining about performance in the long distance market for years, sponsoring studies allegedly showing that this market performs poorly because it is concentrated.¹⁰⁸ Many disagree with their empirical assessment. The long distance market has dozens of competitors in a nation-wide market. Entry barriers are relatively low and prices have fallen substantially. However, the economic theory underlying these ILEC claims is correct. As Professor Hausman concludes, oligopoly facilitates coordinated interaction among competitors.¹⁰⁹ Given the high barriers to entry and the small number of competitors in local service markets, unregulated oligopoly, and particularly

¹⁰⁷ See, e.g., F. M. Scherer and David Ross, *Industrial Market Structure and Economic Performance*, 3rd ed., Houghton Mifflin, Boston 1990, p. 315.

¹⁰⁸ See Testimony of Jerry A. Hausman, on behalf of Pacific Bell (u 1001) May 19, 2000, Before the Public Utilities Commission of the State of California, *in re request of MCI Worldcom, Inc. and Sprint Corporation for Approval to Transfer Control of Sprint Corporation's California Operating Subsidiaries to MCI WorldCom, Inc.* Application No. 99-12-012, p. 12. ("Hausman California Testimony"). See also, *Application by New York Telephone Company (d/b/a Bell Atlantic – New York), Bell Atlantic Communications, Inc., NYNEX Long Distance Company, and Bell Atlantic Global Networks, Inc., for Authorization to Provide In-Region, InterLATA Services in New York*, Declaration of Paul W. MacAvoy in Support of Bell Atlantic's Petition to Provide In-Region, InterLATA Telecommunications Services, CC Docket 99-295, September 1999.

¹⁰⁹ See Hausman California Testimony, p. 12. Hausman points out that "the industrial organization literature has explored how, with only two firms, detection of cheating from an agreement is simplified." Citing, A. Jacquemin and M.E. Slade, "Cartels, Collusion, and

duopoly performance by the ILECs and cable companies, can be expected to be poor.

There is empirical evidence from another telecommunications market that a duopoly does not provide competitive performance. Incumbent cellular providers, of which there were originally a maximum of two in each service market, argued that prices were competitive prior to entry by PCS carriers. However, pricing information collected by the FCC shows that prices declined over 50 percent in the five years since PCS entry began in 1995.¹¹⁰ As the Yankee Group reported, "the rollout of PCS service encouraged the cellular carriers to speed conversion to digital, reduce prices, and offer more services."¹¹¹ It is reasonable to infer that the increase in competition when the market increased from two to as many as six or seven carriers was dramatic. There would be less concern about a duopoly of facilities-based providers of local services if competitors could rely on nondiscriminatory access to unbundled network elements to provide service to their customers.

X. UNEs Are Necessary

From an economic perspective, the ILEC network should be unbundled when doing so provides an opportunity to materially improve consumer welfare. Unbundling can improve consumer welfare by allowing competition for features

Horizontal Merger," in R. Schmalensee & R. Willig, *Handbook of Industrial Organization*, Elsevier Science Pub. Co., New York 1989, Chapter 7.

¹¹⁰ *Before the FCC, In the Matter of Annual Report and Analysis of Competitive Market Conditions With Respect to Commercial Mobile Service*, FCC Document 00-289, Fifth Report, 15 FCC Rcd. 17660 (2000).

¹¹¹ See Mark Lowenstein and Adam Zawel, "The Impact of PCS Service on U.S. Wireless Pricing," Yankee Group, September 2, 1999, p. 66.

and functions as well as by allowing cost competition for those elements of the service that the CLEC provides itself (e.g., customer service and billing). Moreover, unbundling will allow the CLECs to put together packages of local, long distance and broadband services that differ in materially ways from those that an integrated ILEC would offer. Of course, if only the ILEC can offer such packages, the ability of CLECs and IXCs to compete for significant classes of customer business would be reduced, with likely consequent reductions in consumer welfare. Finally, as discussed elsewhere, since unbundled elements are a complement to CLEC facilities-based services, offering unbundled elements can reduce barriers to entry and stimulate competition.

Refusal by the ILECs to unbundle would be consistent with improving consumer welfare only in two cases. First, if there are sufficient alternative competitive local service platforms to provide consumers with an array of choices, then unbundling would be unnecessary.¹¹² Second, if the ILEC could demonstrate that unbundling entails costs that exceed the benefits of added choice, then unbundling would not be required under a consumer welfare test. Sections V-VIII above demonstrate that competitive options are not sufficiently robust to make unbundling unnecessary. ILEC efforts to document costs that exceed the benefits of unbundling have been unpersuasive to regulators. The argument that unbundling deters efficient investment, and thus would harm consumer welfare is discussed below in Section XI.

¹¹² As discussed elsewhere, if there were sufficient alternative local platforms it would be likely that ILECs would voluntarily unbundle in order to compete more effectively with the competitors who owned their own loop facilities.

The legal standard for unbundling under the 1996 Act and court rulings may differ from the economic standard just discussed. Under the Act an element should be unbundled if CLEC ability to offer a service would be materially impaired.¹¹³ Without delving into the legal details, it appears that the legal and the economic standards discussed above are consistent.

CLECs desiring to provide competitive services would be much less effective in doing so without access to UNEs. Consider a new firm formed for the purpose of offering local services that is not affiliated with any incumbent. Cable and wireless links to the consumer are generally not available or do not provide the capacity or the quality necessary to provide consumers with adequate alternatives to the incumbent's services. Therefore, the ability of the CLEC to compete would be impaired if it did not have access to UNEs. With such access, the new entrant CLEC could offer bundled or unbundled service packages to consumers, perhaps with the intention of building its own facilities where economic.

Defining the particular elements that must be unbundled is beyond the scope of this Report. In general, UNEs that a CLEC needs to provide traditional narrowband services, broadband service for Internet access, and high-capacity services for large business customers are required. The case for unbundled loops is obvious given the major barriers to CLEC entry in all but the densest zones, and the difficulty of expanding even within these zones. The discussion in

¹¹³ 47 U.S.C. §§ 251(d)(2)(A) and (d)(2)(B). See also, *In the Matter of Implementation of the Local Competition Provisions of the Telecommunications Act of 1996*, CC Docket No. 96-98,

Section VII shows that even the transport function exhibits substantial economies of scale. A recent Z-Tel analysis shows that the Commission's existing restriction on unbundled switching has reduced competition.¹¹⁴ None of the markets in which these elements are offered is sufficiently competitive to allow an efficient wholesale market to operate. The brief history of the post-1996 Act period conclusively demonstrates that the ILECs will not provide the necessary UNEs to CLECs without intervention by regulators.

This fact alone demonstrates that claims that these facilities are abundant and virtually ubiquitously available are false. If the facilities competition and low barriers to entry and expansion that the Petitioners allege were real, then the ILECs would be anxious to make unbundled network elements available at economic cost to CLECs in order to generate demand on their own networks. Since they do not, and there are not sufficient viable alternatives to guarantee consumers a competitive result, unbundling is required.

The need to unbundle high capacity lines for use by CLECs is the only area where there might be any controversy. But even in this case, using the example of serving a large bank with branch offices throughout the city it was demonstrated in Section VII that unbundling is required.

As the demand for high-speed data services grows, and high-capacity demand is growing across the board, including in areas that the CLEC networks currently do not serve, the availability of high-capacity UNEs can help overcome

Third Report and Order and Fourth Further Notice of Proposed Rulemaking, 15 FCC Rcd. 3696 (1999) ("*UNE Remand Order*"), para. 15.

the substantial barriers to expansion. If traffic can be added to network at an efficient cost through UNEs, it is more likely that the network will be built in the first place.

XI. Unbundling At Economic Cost Will Not Deter Efficient Facilities Construction by Either ILECs or CLECs

ILECs and others have argued that unbundling and TELRIC pricing will deter investment by both ILECs and CLECs. Section A addresses the incentives that CLECs have to build facilities when UNEs are available. Section B deals with ILEC incentives to build new facilities when they are subject to the UNE provisioning and pricing rules. The fact that ILECs do not want to provide facilities even though they would receive an economic return is explained in Section C.

A. UNEs Do Not Reduce CLEC Incentives to Construct Facilities

ILECs have suggested that making UNEs available reduces CLEC incentives to construct their own facilities. If true, this could delay the onset of full facilities-based competition. The ILEC argument is incorrect. Withdrawal or overpricing of UNEs will not encourage the CLECs to build facilities that they would otherwise not build. Simply put, if it is not economic to enter by constructing facilities, then the CLECs will not enter. Only if UNE prices are set below economic cost would CLECs have an incentive to postpone otherwise efficient construction of new facilities.

¹¹⁴ See "An Empirical Exploration of the Unbundled Local Switching Restriction," Z-Tel Public

It should also be noted that artificially high UNE prices would not induce entry, even if the CLECs can produce services at a cost in between the ILECs' TELRIC costs and the artificially high UNE prices. It would be foolhardy for the CLECs to do so because they would anticipate that the ILECs would lower prices in response to entry, and cause them to lose money.

Withdrawing UNEs would actually have the effect of reducing CLEC investment. ILEC UNEs are in some cases a complement to CLEC facilities, in effect allowing CLECs to obtain the benefits of ILEC economies where the CLECs cannot efficiently construct their own facilities. In some cases, only by combining unbundled ILEC facilities with their own, can the CLEC achieve the economies needed for successful entry. Denying CLECs the opportunity to use this complementary input only reduces the incentive and ability of CLECs to invest in their own facilities.

It must be remembered that facilities construction by competitors is not desired for its own sake. The investment enhances consumer welfare only if the competitor is ultimately as or more efficient than the incumbent. If the presence of substantial economies of scale dictate that there be only one supplier, then entry by a second facilities-based firm will generally not add to consumer welfare.¹¹⁵

Firms might enter in the face of substantial incumbent economies of scale in some circumstances. For example, if the firm believes that it has other

Policy paper No. 3, November 2001.

advantages that can compensate for its higher costs, or if it expects to achieve its own economies over time, it will enter anyway. But pricing UNEs above costs or withdrawing them from the market (the equivalent of an infinite price) will not change this calculation.

B. UNEs Do Not Reduce ILEC Incentives to Construct Facilities¹¹⁶

The ILECs argue that being forced to make UNEs available at economic cost reduces their incentives to invest in new facilities. Three related arguments are advanced. First, the ILECs argue that TELRIC prices are inherently inappropriate. That is, they are incapable of sending the right signals to the market, either because it is too difficult to estimate them properly or because the concept itself is flawed. Second, they argue that investment in facilities will be stranded once CLECs build their own facilities, leaving ILECs with unrecovered investments. Third, they argue that forcing the ILEC to sell the facilities incorporating new technology at TELRIC prices denies them the opportunity to be compensated for the risk they have taken. Each of these arguments are discussed below, beginning with the allegation that TELRIC is inherently flawed.

¹¹⁵ Entry by firms reselling the monopolist's services or using its network elements facilities could provide consumer welfare benefits by giving consumers additional choices and the benefit of retail competition.

¹¹⁶ These issues are discussed by William J. Baumol, "Response to the NTIA Request for Information on Broadband." (Baumol Paper") See, U.S. Department of Commerce, National Telecommunications and Information Administration ("NTIA"), *Notice, Request for Comments on Deployment of Broadband Networks and Advanced Telecommunications*, Docket No. 011109273-1273-01, November 14, 2001 ("NTIA Broadband Deployment Request").

1. *TELRIC Is an Appropriate Costing Concept*

TELRIC is designed to compensate the ILEC for the economic cost of building and operating new facilities— as the Commission found in the *Local Competition Order*.¹¹⁷

The pricing principles underlying TELRIC are unassailable. In competitive markets, prices are based on economic cost, and implicitly on the investment and expenses that an efficient new entrant using modern technology would incur.¹¹⁸ Higher prices would induce entry and lower prices would induce exit. Some telephone companies in the U.S. have criticized TELRIC because it does not rely on the existing telephone company infrastructure to compute costs. However, in a competitive market the existing infrastructure of any particular competitor is irrelevant to the pricing calculus. As discussed above, prices in a competitive market are based on the most efficient technology and practices. In other words, whatever technology was deployed or when or at what cost it was deployed do not affect prices in competitive markets. By advocating the measurement of costs using their existing network configurations, the ILECs are attempting to find ways to recover their embedded costs. If the FCC were to accept this, it would be putting the interest of a particular competitor ahead of the interests of competition.¹¹⁹

¹¹⁷ *Local Competition Order*, para. 685.

¹¹⁸ Companies in the competitive U.S. long distance market have written off billions of dollars in investments as technology has progressed from analog microwave to digital microwave to and through several generations of fiber optic transmission technology.

¹¹⁹ If the ILECs insist on setting prices based on their actual network, then they should compute a Long Run Incremental Cost ("LRIC"). This LRIC cost must be lower than TELRIC or else the ILECs would have already scrapped their entire network.

The ILECs can hardly oppose the application of economic pricing principles to regulatory pricing decisions. ILECs have historically advocated incremental cost pricing for services subject to competition and specifically rejected pricing based on embedded costs.¹²⁰

Finally, if anything, as actually implemented, the TELRIC prices are conservatively high. TELRIC, as implemented by the FCC takes existing telephone company wire center locations as given. Thus, the modeled network is not as efficient as it could be. The TELRIC Models used by the states to estimate UNE prices are conservative in other ways as well. The states have generally, and in many cases inappropriately, adopted input cost assumptions that are too high or have otherwise approved UNE rates well above true TELRIC levels.

2. *Stranded Plant Is Not A Real World Problem for the ILECs*

Network unbundling is unlikely to produce stranded plant. To be stranded, an investment in an asset must be sunk. Switching capacity and electronics obviously can be reused or resold even if demand for other elements of the network declines. As a matter of first impression, loops appear to fit into the category of sunk costs. However, in reality, most loop plant is shared by numerous customers. Most feeder and distribution investment is common to all the loops provided. The wire pair serving a particular customer can be reallocated to another customer if the first customer's business is lost to a competitor. Only the drop and NID are unique to a particular customer.

¹²⁰ See Baumol Paper, p. 10. (Citing Federal and State decisions discussing BOC positions.)

However, even if that particular customer is lost to a competitor, the investment does not become worthless. It is an asset that can later be used to compete for the business of that customer or a new customer at that location at a later time.

It is also important to note that overall ILEC local network demand is unlikely to decline. The market is growing and experience with competition around the world demonstrates that incumbents typically do not lose actual business. Competitors generally take a larger share of incremental business. This is similar to experience in the long distance business. From the introduction of switched competition in 1978 to 1999, AT&T lost market share but continued to grow in absolute size.¹²¹ With growing demand, switching, transport and most loop plant will not be stranded by losses of incremental business to competitors.

If ILECs are concerned about stranded plant, they should encourage entrants to use UNEs. If cross-platform competition is the threat they allege, then one way to compete is to unbundle and allow CLEC competitors to market network elements for them. A related point is that increasing prices to reflect an alleged options risk may be counter-productive for an incumbent because the resulting higher interconnection charges may simply accelerate the investment by competitors in networks of their own.

The ILECs also forget the fact that technological change can increase the value of existing assets. Digital switching made ILEC investments more valuable because it enabled the offering of high margin vertical and ancillary services such

¹²¹ See Trends in Telephone Service, Table 10.7, p. 10-13.

as voice mail and custom calling features. Similarly, the demand for broadband connections has increased the value of embedded networks in recent years.

Finally, TELRIC rates include a return to capital that includes a risk factor and allow for the depreciation of investments. Thus the TELRIC tool is sufficiently flexible to account for the risks that the ILECs say they have. The weighted average cost of capital estimated by traditional means already reflects the introduction of competition and the advance of technology. These factors have been in the market for many years.¹²² The ILECs have simply failed to marshal the evidence to convince regulators that rate should be higher. Instead, they have chosen to fight the concept.

3. *Unbundling Is Consistent With Innovation Incentives*

The argument that unbundling at TELRIC prices will deter ILEC innovation was made most recently by Alfred Kahn and Timothy Tardiff, in the context of broadband services. They maintain that "the more innovative the investments contemplated, the greater the uncertainties, both technological and commercial, the greater the risks, the more important is the prospect of the investor's exclusive enjoyment of the fruits of the ventures that turn out successfully."¹²³ As a matter of pure economic theory they are, of course, correct. Where the argument breaks down is in the application of the theory to the facts.

¹²² It should also be noted that the cost of capital in the models being used to produce TELRIC rates for UNEs has typically remained in the 10 to 12 percent range even though interest rates, which are a significant component of the cost of capital have fallen substantially in recent years.

¹²³ Declaration of Alfred E. Kahn and Timothy J. Tardiff, December 18, 2001, submitted to NTIA, para. 14.

The ILECs did not pioneer the type of broadband service that Dr. Kahn and Mr. Tardiff are discussing. The Internet, the development of which is driving the demand for broadband services, has evolved independently of the ILECs. The market position enjoyed by the cable companies demonstrates that they were in fact the leaders in taking the risks in deploying broadband services. Moreover, in terms of DSL, it was the CLECs who made the initial investments and took large investment risks in doing so. The ILECs have been followers. Now that the demand has been proven, largely due to the investments of others, they wish to prevent the original risk takers from using their networks.

It is also important to note that much of the technology risk inherent in deploying new ILEC telecommunications services has already been borne by the equipment manufacturers. ILECs are responsible for few innovations. They have depended on a competitive equipment market to come up with new process or service innovations.

The amount of the risk that ILECs must take in incurring capital expenditures to implement DSL is also questionable. On ordinary copper loops, the additional investment is both moderate and scalable. Where DLC systems are being used by the ILEC, operational cost savings can justify much of the cost of necessary network upgrades. In other words, ILECs have the incentives to make much of the investment whether or not they provide broadband services. The investments that are specific to broadband are again modest and scalable.

It should also be noted that many of the revenues from new services are from services that are not regulated. Rapid deployment of broadband will allow

ILECs to compete for the substantial unregulated revenue streams generated by ISPs and other firms serving broadband users. The ISP function includes arranging for consumer access to the Internet through local links. The ISP bills consumers for the connection and provides customer support functions. The ISP may also provide content and services such as customized web pages, web hosting, e-mail server provision, e-mail roaming, IP addresses (static or dynamic), access to domain name search and registration, browser and search engines, antispam software tools, Instant Messaging, streaming audio and video feeds, public radio station broadcasts, community bulletin boards and other local content, and technical seminars and workshops. The ILECs are free to make market returns on these services, but only if they make the investments necessary to allow consumers to have reasonably priced broadband service.

Finally, the ILECs' stated reluctance to roll out DSL services more rapidly, including DLC rollout, is hard to reconcile with their claims that the broadband market is competitive. By slowing the rollout of DSL plant, the ILECs are leaving the market open for cable.

In general, the unbundling requirements in the 1996 Act did not deter ILEC investment. Indeed, as the chart below shows, ILECs actually increased their investment activity after the Act passed. It is possible that much of this investment was due to the desire to provide broadband services in competition with cable companies and the data local exchange carriers ("DLECs").

Figure XI.1
Total BOC Plant Additions



C. Why Are ILECs Withholding UNEs from the Market?

If UNE rates provide the ILECs with a compensatory return, then why do the ILECs resist providing the services? The answer appears to be that the ILECs are withholding facilities not because UNEs are below the ILECs economic cost. They are withholding facilities because the UNE price is below the ILEC opportunity cost.

ILECs continue to earn substantial profits on their legacy lines of business. New technology, including DSL provided over their facilities by CLECs may be perceived as a threat to existing revenue streams. One example is T1 rates. T1s are provided over ordinary copper loops (and DLC) using DSL technology. The ILECs charge high rates for these services. For example, in Illinois, a five mile DS-1 circuit will cost \$316 per month.¹²⁴ Making the constituent parts

¹²⁴ Based on Zone 2 and a five year term commitment.

available for resale through unbundling will put these high returns at risk. The ability of ISPs or CLECs to use unbundled broadband elements and resold DSL services to compete for high margin local service customers using voice over DSL, as discussed in Section VIII, will also result in arbitrage.

This is, of course, exactly what unbundling and resale policies are supposed to do. Unbundling and resale applied to AT&T's long distance service in the early days of long distance competition led to significant changes in AT&T's rate structure, and significant benefits to consumers.

So the answer is that ILECs resist UNEs not because they cannot earn a competitive return on them, but because they risk losing a monopoly return on their existing services.

Appendix A – Traffic Demand Estimates

According to the Cellular Telecommunications and Internet Association ("CTIA"), the average duration of a completed wireless call as of June, 2001, is 2.62 minutes¹ and average monthly usage is about 422 minutes/month.² Using a conservative assumption of twenty-two days per month and a 70% call completion fraction (*i.e.*, 70% of all call attempts result in a completed call) and a further assumption that 10% of daily traffic falls in the busy hour, an average wireless offered traffic load per subscriber is computed as SHOWN IN Table A.1.³

Table A.1
Wireless Offered Load per Subscriber

Average completed calls/month	= 422 minutes/month ÷ 2.62 minutes/completed call = 161 completed calls/month
Average completed calls/day	= 161 completed calls/month ÷ 30.4 days/month = 5.3 completed calls/day
Average completed calls/busy hour	= 5.3 completed calls/day × 0.1 = 0.53 completed calls/busy hour
Average call attempts/busy hour	= 0.732 completed calls/busy hour ÷ 0.7 completed calls/call attempt = 0.76 call attempts/busy hour
Average offered traffic/sub	= 0.76 call attempts/BH × 2.62 min/call × 60 s/min ÷ 100 s/CCS = 1.19 CCS, or about 1.2 CCS.

¹ Cellular Telecommunications and Internet Association (CTIA), "CTIA's Semi-Annual Wireless Industry Survey Results – June 1985 to June 2001," ("CTIA Survey"), available at <http://www.wow-com.com/industry/stats/surveys/>. Although more recent estimates of penetration are available, CTIA's June, 2001, numbers are used for consistency.

² See, e.g., Jeffrey Selingo, "Complaints skyrocket along with cellphone use," *The New York Times*, reprinted in *The Denver Post*, February 18, 2002.

In comparison, typical wireline telephone per-subscriber offered loads range from around 3 CCS to 10 CCS or more, depending on whether the service is business or residential, and what features the subscriber has selected. For example, the Call Waiting feature (which inserts a tone into the called party's end of an active telephone call to let the subscriber know another call is waiting) can increase the per-subscriber traffic by a factor of two to four or so. Business lines typically exhibit higher offered loads than do residential lines.⁴ This is assuming an average (business and residential) offered load per wireline subscriber of about 3.6 CCS, which is three times the conservatively-estimated 1.2 CCS per wireless user.

³ See, e.g., Telcordia Technologies, *LSSGR: Traffic Capacity and Environment*, GR-517-CORE, Issue 1, December, 1998, for discussions of telephone subscriber traffic characteristics.

⁴ *Ibid.*, p 6-8.

Appendix B – Wireless Network Capacity

As of June, 2001, there were about 118 million cellular and personal communications service ("PCS")¹ subscribers in the U.S. served by about 114,000 cell sites.² The average number of subscribers per cell is thus just over 1,000. Obviously, there is a wide variance in the actual number of subscribers per cell. Many rural cells will serve very few subscribers, and urban cells will serve considerably more than the nationwide average. In rural Western areas, for example, there are cells that only cover major highways to serve roamers, and there may be no, or very few, "permanent" subscribers residing in the cell coverage area. For the purposes of this capacity analysis, however, 1,000 subscribers per cell is assumed. This is a very optimistic approach, as it leads to significant underestimates of the cell capacity required in urban areas just to serve existing wireless subscribers. The analysis will show that, even in this optimistic case, wireless systems cannot come close to serving both wireless and wireline demand in areas with urban and even suburban subscriber densities.

The following discussion of wireless network capacity is based on code division multiple access ("CDMA") radio technology as it is used in existing U.S. cellular and PCS systems. CDMA is used in our examples as it generally has somewhat greater capacity for a given amount of spectrum than competing

¹ In this section, the term "wireless" is used to refer to both cellular and personal communications mobile and portable service offered by service providers classified as Commercial Mobile Radio Service ("CMRS") system operators.

² CTIA survey.

technologies. It is, however, considerably more complex to analyze than are more conventional technologies.

All cellular and PCS technologies are designed to reuse frequencies in a serving area to attempt to maximize the use of the available spectrum.

"Conventional" (time division multiple access ("TDMA") and analog cellular) systems require significant physical separation between cochannel cells (cells using the same radio channels). CDMA systems can reuse frequencies in adjacent cells and even within a cell when cells are divided into angular sectors (see Figure B-1). This ability to reuse frequencies in adjacent cell coverage areas is the principal reason for CDMA's capacity advantage over other technologies.

The capacity of a CDMA system, considered at the cell level, is difficult to estimate and depends on many parameters, including the amount of spectrum (number of radios) employed, the coding rate used for the digital voice coder, the number of sectors into which the cell is divided, cell transmitter power, and a number of others. In CDMA, subscribers occupy the same spectrum simultaneously, as opposed to, say, TDMA, in which each subscriber is assigned a time slot on a specified frequency channel for the duration of the call. Active CDMA subscribers thus generate mutual interference, and it is this interference which ultimately limits the performance and capacity of the system.³ As shown in

³ Note that there is generally no precise limit to the capacity of a CDMA system. Each active user generates interference for all other active users. As usage increases in a cell (and in surrounding cells), the interference level increases for all users, and signal quality can deteriorate to unacceptable levels, causing users to terminate their calls. This is analogous to a number of people trying to converse in a crowded room, in which all talkers share common (acoustic)

Figure B.2, interference is generated by users within a cell as well as by users in other cells. As user activity varies among cells, the effective capacity of a given cell will change. The capacity of a given cell will increase as activity in adjacent cells decreases and produces less interference; conversely, increased activity in adjacent cells will lower the useful capacity of the given cell. Also, the effective coverage area of the cell increases as average interference from adjacent cell decreases, leading to a well-known characteristic of CDMA systems often referred to as cell "breathing."

Using typical assumptions for the various system parameters as outlined in the previous paragraph, we estimate that a CDMA system will support about seventeen active users per radio. Under standard Erlang B assumptions, this corresponds to a per-radio traffic capacity of 384 CCS,⁴ which can support about 320 users under our assumption of 1.2 CCS per mobile/portable subscriber. For our average cell demand of 1,000 users, four radios are required in an omnidirectional cell, leaving an excess capacity of 336 CCS for fixed users, or about 93 fixed users at 3.6 CCS/user.

If more than about four radios are required in a cell, carriers subdivide the cell into sectors, each of which is equipped with radios and antennas separate from those in other sectors. The most common approach is to equip three

spectrum simultaneously, and the interference from other conversations causes people to leave the room to carry on their conversations elsewhere.

⁴ This assumes two percent blocking at the radio channel level, a typical design value for wireless systems. This is, of course, twice the overall blocking level one normally associates with wireline telephone service.

sectors.⁵ In estimating the capacity of a CDMA sectored cell in which radio channels are reused in each sector, one generally applies a sectorization efficiency factor of 0.85, so that the capacity of the entire three-sector cell is 3 x 0.85) or 2.55 times the capacity of a single sector.

Technical and economic considerations limit the number of radios in a sector to about four. For a three-sector cell, the maximum capacity is thus 384 CCS/radio x 4 radios/sector x 2.55, or 3916 CCS. This capacity can serve 1,000 mobile/portable users and about 750 fixed subscribers.⁶ If the cell has a nominal coverage radius of 1 km (0.62 miles), the wireline subscriber density capacity is only 620 subscribers/square mile, which is far below even what could normally be considered a suburban subscriber density. It is important to keep in mind that these values are based on severely optimistic assumptions regarding wireline subscriber traffic, existing wireless subscribers per cell in urban and suburban areas, and other factors.

Even with these optimistic assumptions, existing wireless systems cannot even approach the levels of capacity required to serve significant fractions of wireline users. If it is supposed that each of six wireless service providers in a

⁵ Although equipment vendors normally offer six-sector cell designs, they are rarely used as they are expensive and quite difficult to install and support.

⁶ As noted elsewhere, the capacity estimates used in this report are based on a 9600 bps voice coding rate (known as Rate Set I), which provides voice quality that is apparently acceptable for mobile and portable use but is substandard in comparison with the overall voice quality of wireline voice service which uses a different class of voice coding techniques which usually operate at 64 kbps. The U.S. CDMA standards allow for a 14.4 kbps voice coder (Rate Set II) which offers voice quality that is somewhat better than that provided by the Rate Set I coder but which is still inferior to current wireline quality. If the radios added to each cell site to serve fixed users used the 14.4 kbps voice coders to attempt to meet subscriber expectations of voice quality, the number of active users per sector per radio becomes eleven instead of the seventeen used in the initial analysis. Note that this analysis is particularly conservative because, to the best of our knowledge, Rate Set I is not generally used in commercial service.

market assign as much capacity as possible in each cell to serve mobile/portable users and fixed users for only switched voice service, and that each uses cells with a nominal coverage radius of one kilometer (which assumes an absurdly dense arrangement of cell sites, given that six service providers are involved), the total supported fixed subscriber density is 6×620 , or 3720 per square mile. This is a typical suburban subdivision density and does not come close to urban densities. It is especially important to note that this density could be served only if all carriers were to equip the practical maximum number of radios in a cell to serve relatively high-usage and equally relatively low-revenue fixed subscribers.

The preceding analysis assumed a nominal cell coverage radius of 1 km. The served subscriber density will obviously increase if the cell radius is smaller, and, in the absurd limit, one could claim (and some have)⁷ that arbitrarily large subscriber densities could be served by continuing to reduce the average cell coverage radius. This ignores a number of economic and technical realities, including the difficulties in obtaining suitable real estate for cells in densely-populated areas, obtaining zoning and environmental approval for antenna masts, leasing or constructing backhaul facilities to connect cell sites with the wireless switching center controlling the wireless network, as well as solving the myriad technical problems arising from the need to pack a large number of radio carriers in a single cell, many of which become intractable at short cell spacings.

⁷ *The Enduring Myth of the Local Bottleneck*, 1994, p 34 (unattributed). The author of this document states that "... cellular architecture is inherently expandable, like an accordion. The capacity of all cellular systems, including PCS, can be increased almost indefinitely by deploying additional cells and thereby reusing already-allocated spectrum." This statement reflects an acute lack of understanding of cellular radio technology and its practical limitations.

Initial forms of third generation ("3G") radio technology now being introduced by some carriers will not likely improve capacity to allow significant degrees of wireline service replacement. These new technologies are in fact not intended to do any such thing. The 1xRTT CDMA technology that is now in early phases of commercial deployment includes improved voice processing techniques that can increase voice capacity in a single 1.25 MHz carrier by up to a factor of two. 1xRTT also provides high-speed (144 kbps) packet data in the same carrier space. It is easy to misinterpret the advertised benefits of this technology: It does not simultaneously double voice capacity and add high-bit-rate packet data. The improved voice capacity is intended to serve existing voice demand with less of the carrier capacity than was previously required, thus making "room" for the new packet data capability. It should also be noted that the high-speed data signal is shared among many users using multiple-access techniques and thus must not be viewed as an average bit rate available to each subscriber. The actual average rate supported per user will be much less than the peak rate of 144 kbps, and probably in the range of a few tens of kilobits per second.

Appendix C – ATM service classes and functions

The Asynchronous Transfer Mode (“ATM”) standards define a range of service categories. The lowest level of service, and that usually supported in common asymmetric digital subscriber line (“ADSL”) implementations, is known as Unspecified Bit Rate (“UBR”). This is sometimes known as a “best-effort” service and carries with it no service quality guarantees. UBR cells carry the lowest priority in an ATM network. Thus, for example, the effective data transmission rate and the delays packets encounter as they travel through the network can and will vary, and the underlying service provider, makes no guarantee regarding the variation of either rate or delay. UBR is useful for applications such as casual Internet access in which variable cell delays are not critical and which do not require quality of service guarantees. It is unsuitable for packet voice, video, circuit emulation (such as DS-1 service) or other more sophisticated applications.

Other ATM service categories include, for example, real-time Variable Bit Rate (“rt-VBR”), which is designed to support such services as packet-switched voice communications. Voice service is particularly sensitive to end-to-end delays in transmission as well as to variations in the end-to-end delay. Excessive delay can lead to “echoes” over a circuit which can be disorienting if the delay is sufficiently long, and unacceptable variations in delay can lead to difficulties in reconstructing the analog signal at the destination. The rt-VBR service category is designed to support such delay-sensitive applications and carries with it service guarantees that ensure a suitable quality of service for

them. ATM, in combination with ADSL and other forms of DSL, can thus readily support packet voice and other advanced services in addition to the relatively simple Internet access. If, for example, an incumbent local exchange carrier ("ILEC") were to make rt-VBR available to competitive local exchange carriers ("CLECs") under suitable rate elements (which would necessarily specify the ATM quality of service parameters required for these higher-level service classes), competitors could offer high-quality packetized voice service over DSL connections. A competitor could also offer advanced video services using ATM service categories with guaranteed quality of service levels.

ATM is a connection-oriented fast packet switching technology and requires a logical association, or virtual channel, between the endpoints of the connection. The term "virtual" is key in this context. Once the virtual channel is established, the network then knows to send all packets generated at one end point to the other end point in the virtual connection. The virtual circuit is just the association of the endpoints of the connection and does not imply anything about network capacity. All packet switching systems make capacity available only on demand. Thus, there is no capacity dedicated to the virtual connection as there is in the physical connection in the circuit-switched case. The most common implementation of ATM virtual channels is the permanent virtual channel ("PVC"). A PVC must be administered; that is, it is set up and removed by a network administrator using a suitable operations support service ("OSS") terminal. A PVC is generally established over a long period, typically months or even years, hence the adjective "permanent." The PVC is the basis for the "always on"

feature often mentioned in conjunction with ADSL service. Because the virtual circuit is permanently assigned, the user does not have to invoke a call setup procedure each time the user wants to communicate with, for example, his or her Internet service provider. Because bandwidth is not dedicated to the PVC, the permanent nature of the virtual connection does not reduce overall network capacity when the user is idle.

ATM also allows for virtual path connections. A virtual path contains a number of virtual channels; a Permanent Virtual Path ("PVP"), for example, can contain several PVCs. PVPs are useful for managing resources. If an ILEC has made PVP connections available to a CLEC, a CLEC can lease PVPs, with associated service categories, and then administer its own PVCs within the PVPs to facilitate serving its subscribers without relying on the underlying carrier for PVC provisioning for individual users.

ILECs, however, have chosen to restrict the ATM service class available on DLC-based ADSL to the lowest, UBR, which by definition has no quality of service guarantees and which is not suitable for end-user services beyond such basic ones as email access and Web browsing. They similarly do not offer PVPs on DLC-based ADSL, thus requiring CLECs to rely entirely on ILEC provisioning and service order processes. SBC Communications, Inc. (SBC"), for example, launched Project Pronto in 2000 in an attempt to upgrade DLC systems in SBC's BOC subsidiaries to support ADSL. In the announcement process, SBC made much of their plans for allowing CLEC access to their DLC-based ADSL services.

But what was to be made available to the CLECs under Project Pronto was quite modest: UBR service and single PVCs, with an explicit exclusion of PVPs.¹ Qwest has a similarly restrictive DLC-based ADSL service that also offers only UBR to CLECs, with no PVP capability associated with the ADSL service.²

¹ For a representative SBC Project Pronto service description for CLECs, see "New Product Announcement Wholesale Broadband Service – California," CLECC00-138, Pacific Bell, May 24, 2000, with specific restrictions concerning ATM class of service and PVPs at p 10, section 9.6.

² "Qwest DSL Services," Qwest Communications International, Inc., Technical Publication 77392, Issue I, September, 2001.

HAI Consulting, Inc.

Statement of Qualifications

General Qualifications

HAI Consulting, Inc. (formerly Hatfield Associates, Inc.) is an interdisciplinary consulting and research firm serving a wide range of clients with stakes in the telecommunications field. Hatfield Associates was founded in February, 1982. With the departure of Dale Hatfield to the FCC in 1997, the remaining associates formed HAI Consulting, Inc. HAI and Hatfield Associates have provided consulting and educational services in nearly all aspects of the present and future telecommunications infrastructure, including local exchange networks, cable television systems, competitive access networks, land mobile and personal communications, long haul terrestrial and satellite communications, data communications, and customer premises equipment.

Principals of the firm include consultants with graduate degrees and decades of senior level experience in engineering, economics, business, and policy/regulation. HAI's services include, among others, regulatory filings and policy studies, engineering studies, expert testimony, market research, economic studies and cost modeling, "due diligence" support, business planning, education and system development. The firm has substantive experience in international telecommunication matters. Consulting and educational services are performed for private and public sector clients in Australia, Canada, Mexico, Chile, New Zealand and several countries in Central and Eastern Europe.

Examples of recent consulting assignments include:

- Development of a widely used cost model to estimate the investments and expenses associated with the provision of local exchange and exchange access and interconnection services;
- Analyzing the potential for competitive entry into the local exchange telecommunications business, presented in papers entitled "The Enduring Local Bottleneck: Monopoly Power and the Local Exchange Carriers" and "The Enduring Local Bottleneck II";
- Testifying in state proceedings on various aspects of competitive entry into local exchange and exchange access services, and on state mechanisms to fund universal service;
- Developing an economic and engineering analysis of the potential of broadband deployment and the role it will play in the national economy, presented in a paper entitled "Economics and Technology of Broadband Deployment."
- Assessing the technological and economic merits of various telephone companies' plans for offering video dialtone services;

- Modeling the cost of telephone service in Mexico;
- Testifying and filing written testimony in proceedings before the Canadian Radio-telephone and Telecommunications Commission on local telephone competition, interconnection, collocation and number portability;
- Representing clients in U.S. state commission-sponsored negotiations to resolve local interconnection and number portability issues;
- Developing a vision statement dealing with the future of cable television networks in providing telecommunications and enhanced video services;
- Authoring the "Telecommunications Technology" and "Utility Applications of Telecommunications" chapters, describing utility opportunities in telecommunications, of a major telecommunications report for the Electric Power Research Institute;
- Analyzing telecommunications opportunities, costs, and modes of entry for several major electric utilities, leading in one case to a decision by the utility to deploy a backbone fiber optics network and partner with other entities in the provision of Personal Communications Services;
- Developing material on telecommunications technology for inclusion in a report on international telecommunications prepared by the Office of Technology Assessment of the U.S. Congress;
- Analyzing trends in telecommunications architectures and technologies for a major computer company;
- Providing tactical advice and computer network support for a client bidding in the FCC auction of 900 MHz Specialized Mobile Radio licenses;
- Assisting a client in the preparation of comments in an FCC proceeding dealing with the future of the private land mobile radio services;
- Assessing opportunities for the branches of the U.S. Military to consolidate their use of wireless communications;
- Providing analyses for an investment firm contemplating a major investment in a paging company; and
- Providing telecommunications education to countries in Central and Eastern Europe.

Richard A. Chandler
Senior Vice President

Richard A. Chandler is a senior vice president with HAI Consulting, Inc., where he performs a range of consulting services for clients, including evaluation of various communication technologies to address specific user requirements, review of large corporate network structures and operations, as well as the evaluation of the suitability of new products for particular markets. Among other assignments as a consultant, he has developed the technical plan for a proposed wireless-based telecommunications system to provide basic internal telephone service as well as international connectivity to the populace of a developing nation. He has worked with a Korean international carrier in the development of the technical and operating plan for a proposed Korean PCS network. Other contracts have involved the development of regional and nationwide architectures for mobile data networks and evaluation of voice compression and automated conferencing systems to support both internal and external investment decisions. He has worked extensively in the wireless communication area, studying Personal Communications Network architectural issues, including radio segment structures, backhaul networks, and interconnection issues for several clients. Most recently, Mr. Chandler has developed sophisticated telecommunications network models for use in determining the costs of telephone service, including local and toll; he has been the principal developer of the Hatfield and HAI Models commissioned by MCI WorldCom and AT&T Corp. for use at the state and national levels in supporting interconnection and universal service filings. He has also written numerous affidavits and declarations dealing with various telecommunications technologies in several regulatory and court proceedings.

Before joining Hatfield Associates (now HAI Consulting, Inc.) in 1986, Mr. Chandler joined Skylink Corporation as Vice President Network Engineering. While at Skylink, Mr. Chandler developed the ground system control and switching architecture and user terminal requirements for the proposed Skylink network. He developed a distributed control structure which allowed for the decentralization of system intelligence, enabling the simultaneous operation of multiple independent subnetworks. He also developed a packet switching mechanism for the network which enables hundreds of interactive users to share a single radio channel for data transmission. He worked jointly with mobile radio and satellite earth station manufacturers to develop preliminary ground terminal and user terminal functional requirements and technical specifications.

Mr. Chandler joined the AT&T marketing organization in 1981, where he initially was a product manager for data switching and adjunct processor enhancements for existing PBX products. In this capacity, he was responsible for coordinating design, development, and manufacturing efforts, developing business case inputs for product pricing, and coordinating training and advertising for the new products. In another assignment within this organization,

he developed product strategies for advanced data switching technologies, including adjunct packet switches for customer data. He also headed a group furnishing technical support regarding product architecture and features to the AT&T field sales force and providing customer requirements to the development and product management organizations.

In 1977, Mr. Chandler joined Bell Telephone Laboratories, where he participated in exploratory studies of new PBX systems for AT&T. These investigations included the review of various switching system architectures and control structures for next-generation private branch exchanges. He designed and developed segments of a laboratory model of a new PBX and coordinated designs and interfaces for the production version of the new machine. He also studied design approaches and circuit modifications to enhance the reliability of new switching systems. In another significant assignment, he worked on packet switching techniques to be applied to a multi-processor control structure, and he participated in the development of specific packet switch designs to be applied as an adjunct to the circuit-switched network fabric for the purpose of switching user terminal-to-host and host-to-host data traffic.

From 1972 to 1977, Mr. Chandler was an electronic engineer with the Institute for Telecommunication Sciences, a telecommunications research organization within the U.S. Department of Commerce. While at ITS, he performed microwave propagation studies for atmospheric paths in the 60 GHz region, and he developed experiments for studies of space-to-earth paths at 20 GHz and 30 GHz. He also designed experiments and associated instrumentation for availability studies of short atmospheric optical paths in the near infrared. In addition, he participated in and coauthored an extensive review of existing and future cable television technology. He managed a project for the U. S. Department of Transportation for the evaluation of the applicability of tracking radar techniques to vehicular braking systems, and he managed a consulting contract with the National Oceanic and Atmospheric Administration for the technical evaluation of various commercial microwave positioning systems used in hydrographic surveying.

Mr. Chandler received B.S. and M.S. degrees in electrical engineering from the University of Missouri and an M.B.A. from the University of Denver. He pursued additional graduate work in electrical engineering at the University of Colorado. He serves as an adjunct faculty member at the University of Colorado and the University of Denver and teaches graduate-level courses in telecommunications technology, including wireless and cellular communications and digital switching and transmission.

**A. Daniel Kelley
Senior Vice President**

Dr. Kelley specializes in economics and public policy analysis for long distance, competitive local exchange, mobile communications, and cable television clients. Since joining HAI in 1990, he has been involved in antitrust and regulatory investigations that address cost allocation, cross subsidy, and dominant firm pricing. He has authored or co-authored papers submitted in the Federal Communications Commission's Video Dialtone, Advanced Intelligent Network, and Cable Rate Regulation proceedings. In addition, he has advised clients on the Computer III, Open Network Architecture, Access Transport Competition, Price Cap, and Local Interconnection proceedings. Dr. Kelley has provided expert testimony on competition, cross subsidy, interconnection and universal service issues before the Federal Communications Commission and the California, Colorado, Connecticut, Florida, Georgia, Hawaii, Maryland, Massachusetts, Michigan, Oregon, New Jersey, and New York Public Utility Commissions.

His international experience includes advising the governments of Chile and Hungary on competition and privatization and advising private U.S. corporations on competition and interconnection issues in Mexico and New Zealand. Dr. Kelley has participated in State Department sponsored seminars and University level instructional courses in the Czech Republic, Hungary, Poland, the Slovak Republic and Slovenia.

Prior to joining HAI in 1990, Dr. Kelley was Director of Regulatory Policy at MCI Communications Corporation. At MCI he was responsible for developing and implementing public policy positions on the entire spectrum of regulatory and legislative issues facing the company. Matters in which he was involved included the MFJ Triennial Review, Congressional Hearings on lifting the Bell Operating Company Line of Business restrictions, Tariff 12, Dominant Carrier Regulation, Local Exchange Carrier Price Caps, and Open Network Architecture. He also managed an interdisciplinary group of economists, engineers and lawyers engaged in analyzing AT&T and local telephone company tariffs.

Dr. Kelley was Senior Economist and Project Manager with ICF, Inc., a Washington, D.C. public policy consulting firm, from 1982-1984. His telecommunications and antitrust projects included analysis of the competitive effects of AT&T's long distance rate structures, forecasting long distance telephone rates, analysis of the FCC's Financial Interest and Syndication Rules, and competitive analysis of mergers, acquisitions and business practices in a variety of industries.

From January 1978 to September 1982, Dr. Kelley was with the Federal Communications Commission. At the FCC he served as Special Assistant to Chairman Charles D. Ferris. As Special Assistant, he advised the Chairman on

proposed regulatory changes in the broadcasting, cable television and telephone industries, analyzed legislation and drafted Congressional testimony, and coordinated Bureau and Office efforts on major common carrier matters such as the Second Computer Inquiry and the Competitive Carrier Rulemaking. He also held Senior Economist positions in the Office of Plans and Policy and the Common Carrier Bureau.

Dr. Kelley was a staff economist with the Antitrust Division, U.S. Department of Justice, from September 1972 to January 1978. At the Justice Department he analyzed competitive effects of mergers and business practices in the cable television, broadcasting, motion picture, newspaper and telephone industries. As a member of the economic staff of U.S. v. AT&T, he was responsible for analyzing proposals for restructuring of the Bell System.

Dr. Kelley received a Ph.D. in Economics from the University of Oregon in 1976, with fields of specialization in Industrial Organization, Public Finance and Monetary Theory. He also holds an M.A. in Economics from the University of Oregon and a B.A. in Economics from the University of Colorado. He has published numerous articles on telecommunications economics and public policy and regularly participates as a speaker at academic and industry conferences.

David M. Nugent
Associate

Mr. Nugent participates in a wide range of HAI consulting projects. He specializes in quantitative analysis and complex cost modeling related to these projects. Since joining HAI, Mr. Nugent has played an active role in the development of the HAI Model. Recently, he was responsible for the development and implementation of an algorithm that computes efficient ring systems from a data set consisting of known wire center locations. This algorithm was incorporated into the HAI Model 5.0, where it is used to compute interoffice network facility distances. Outside of development work, Mr. Nugent has used the HAI Model to conduct a number of specialized analyses for a variety of clients.

In addition to his experience with the HAI Model, Mr. Nugent co-authored an engineering-economic analysis addressing the potential for facilities-based competition in the local exchange market. This analysis considered cable telephony and wireless local loops as alternative local access technologies. Mr. Nugent focused on the cable telephony portions of the study where he evaluated the status of existing cable systems, the cost of network upgrades, cable telephony revenue opportunities, and the availability of cable telephony equipment.

Mr. Nugent participated in an evaluation of Local Multipoint Distribution Service (LMDS) as a broadband access technology. Although this analysis considered the regulatory and economic aspects of LMDS, Mr. Nugent's responsibilities revolved around the technology of LMDS, where he examined system capacity, hardware, and the cost associated with the network buildout.

Mr. Nugent has played key roles in a number of additional projects including the estimation of damages in several class action lawsuits. Mr. Nugent also participated in the FCC's simultaneous multiple round auction for the sale of 900 MHz spectrum. His responsibilities included the configuration of a remote bidding system and the design of auction analysis and tracking tools.

Before joining Hatfield Associates, Mr. Nugent was a programmer/analyst with American Electric Power. At AEP he was responsible for drafting specifications and coding data acquisition systems used in support of a nuclear generating facility. The majority of Mr. Nugent's time was devoted to writing specifications for real-time plant monitoring systems.

Mr. Nugent is a Summa Cum Laude graduate of Ohio University and holds a B.S. degree in Computer Science. He also holds an M.S. degree in Telecommunications from the University of Colorado.